Form CF Supplementary Information
NASA Resources for the Support of
Ground Based Research in Microgravity Combustion Science

Introduction

At the NASA Glenn Research Center (GRC) the staff is working to improve the effectiveness of the ground-based combustion research program so that new investigations are more quickly prepared to begin test operations and mature their research for early space-flight opportunities. One objective is to encourage designs of new reduced-gravity experiment packages such that they can be operated in both drop towers and aircraft using standard components.

This document is intended to provide some introductory information about the ground-based reduced-gravity testing facilities, some existing combustion test packages that can be used on a shared basis, and some components/subsystems that could be used to build new experiment packages. These descriptions are intended to assist those proposing new experiments in providing NASA with estimates of resources needed to conduct their work.

NASA Ground-Based Reduced-Gravity Test Facilities

The NASA ground-based reduced-gravity research facilities that support the microgravity combustion program includes two drop towers at the NASA Glenn Research Center (GRC) and the KC-135 aircraft.

The 2.2 Second Drop Tower Facility. This drop tower at GRC provides 2.2 seconds of low-gravity test time using vertical free fall for experiment packages with up to 125 kilograms of hardware. The experiment package is enclosed in a drag shield, where the only resistance to free fall is the air drag associated with the relative motion of the package within the enclosure of the drag shield. During testing a net gravitational acceleration of less than 10^{-4}g is obtained. At the end of a drop, the drag shield and the enclosed experiment are decelerated by an inflated airbag. The peak deceleration rate is approximately 30g. The facility is capable of eight to twelve drop tests each day. On-board batteries supply experiment power. Data from experiments are acquired using on-board data acquisition and imaging systems.

The 5 Second Drop Tower Facility. The 5 second drop tower at GRC, also known as the Zero-Gravity Research Facility, has a 132-meter vertical free fall distance inside a vacuum chamber evacuated to 1 Pa pressure. Experiments utilizing hardware weighing up to 450 kilograms are mounted in a one-meter diameter by 3.4-meter high drop bus. Gravitational acceleration of less than 10^{-5} g is obtained during the 5.18 second drop time. At the end of the drop, the bus is decelerated in a 6.1-meter deep container filled with small pellets of expanded polystyrene. The average deceleration rate is approximately 35 g with peak rates up to 65g (for 20 millisec). Typically seven drop tests are performed each week. On-board batteries supply experiment power. Data from experiments are acquired using on-board data acquisition and imaging systems.

The NASA Reduced-Gravity Aircraft Facility. The NASA KC-135 provides up to 22 seconds of low gravity by flying a parabolic trajectory. Near-zero gravity levels, +/- 10^{-2} g, are experienced by experiment packages operated attached to the aircraft cabin floor. Experiment packages may be "free-floated" in the aircraft cabin to obtain gravity levels as low as 10^{-4} g, but useful test time may be reduce depending upon their size. The aircraft is capable of providing "partial gravity" environments including Lunar (0.16g) and Martian (0.38g) levels. Normally an experiment participates in a week-long flight

campaign of four flights, approximately 40 parabolas per flight. Several experiments can participate in a single flight and qualified observers or operators may accompany and operate their experiment packages. The aircraft can supply a total of 80 amps of 28 volt dc, 50 amps of 110 volt ac 60Hz and 20 amps on each phase of 3 phase 110 volt ac 400 Hz. Data from experiments are acquired using on-board data acquisition and imaging systems.

Existing Microgravity Combustion Testing Packages

Four **General Purpose Combustion Rigs** provide a 10" diameter by 21" long closed test chamber equipped with 4 orthogonal windows at the chamber mid height. Two opposing windows are 4" in diameter; and the other two are 4" x 6." Due to the size of the chamber and the drop frame, only 3 windows are accessible at a time; however the chamber can be rotated to select which three. Maximum chamber operating pressure is 4 Atm, maximum oxygen concentration is 30%. Four signal/power/igniter wire pairs and 4 type K thermocouple wire pairs are provided in the chamber. Data acquisition and control is via a "DDACS" type computer (see below). Power is available at 28, 12, and 5 VDC. Support for 2 video cameras is provided for external viewing and recording. A gas flow system provides metered fuel flow for gas jet experiments. Utilization of the rigs is generally heavy, so their availability is not guaranteed. In general, they are unavailable in the summer months; time is often available during October through April. The rigs are not available for use away from the GRC. Use of the rigs requires approval by NASA GRC and will require GRC-led coordination with other users. All changes made to the rig by a user must be fully reversible with limited effort (users will likely be required to return the rig to its original condition upon completion of their testing). Users will have to provide their own optics plate, video cameras, and chamber internals unless their needs match an existing configuration.

Standard Component / Subsystems

Standard Test Package Frame. Standard frames are available that can be used in the 2.2 second drop tower the 5 second "Zero Gravity Facility" and the KC-135 aircraft. The frames are a lightweight shell manufactured from hardened aluminum, with internal dimensions of 16" x 38" footprint x 34" tall. Shelving, other mounting structures, and structure needed to supplement mechanical strength (especially for aircraft use), are the responsibility of the experimenter. The cost of the standard test package frame is approximately $800 including materials, machining, forming and joining.

Combustion Chamber. A "standard" cylindrical aluminum combustion chamber design, 10" diameter x 20" long, is available. Four orthogonal window ports, 4" wide x 6" tall rectangles, are located at the chamber mid-height. The chamber top and bottom flanges are secured using a V-band clamp. Provisions are made in the flange design to pin the flanges for alignment purposes. Chamber penetrations are normally through the chamber bottom, for "permanent" elements and through the top for things that need to be frequently extracted from the chamber. The chamber is currently rated for up to 6 Atmospheres maximum working pressure, depending upon the material and thickness of the windows that are provided by the experimenter. All windows, plumbing, electrical wiring, experiment specific hardware, diagnostics hardware, etc., and the design and fabrication of the chamber installation into the test apparatus are the responsibility of the experimenter. The unit chamber cost is approximately $8,000.00, including materials, parts, machining, and surface treatments.

Power Distribution Module. A Power Distribution Module (PDM) provides eight (8) opto-isolated relay switched circuits (2@20A max, 6@3A max), operable via remote TTL-level command and also by panel mounted switches. The PDM provides 3 isolated DC voltage supplies (bulk 12V @ 6A max-6 ports, low-

noise 12V@500mA - 4 ports, and one user-configurable low-noise supply (12V/500mA, +/-12V@250mA, +/-15V@200mA, or 5V@1A). Inboard fusing is provided for the 4A relays and DC voltage supplies to ensure protection of these devices against overloads, and panel mount fuses are provided for configuring the high-current relays, for loads such as cinema cameras, motors, and heating devices. Input power from two sources (battery modules) is required in order for the PDM to provide the maximum rated current. The nominal PDM enclosure dimensions are 13 x 7 footprint x 2 inches tall, not including connectors and mounting flanges. The PDM cost is approximately $4500 including materials, parts, machining and wiring.

Data Acquisition and Control Systems.
The Droppable Data Acquisition System (DDACS) is based on a mature, ruggedized system consisting of a 68332-based Onset Tattletale™ model 8 datalogger, operating at up to 16MHz, with 1MB onboard memory, and a pair of NASA developed support boards which provide ancillary functions, including 20 channels of opto-isolated digital I/O (16 out, 4 in), and eight (8) channels of programmable-gain, differential analog input (12-bit A/D conv). The DDACS is housed in a 5"x7"x2" enclosure, utilizes rugged connectors for signal and power connections, and is programmed using a variant of the BASIC language (2Ksamples/sec/channel max) or in AZTEC C (100Ksamples/sec max).

The DDACS requires an external computer (Windows or MAC) to upload programs, transfer keyboard commands, and for downloading post-test data. Simple communication software is available. The DDACS cost is approximately $4000 including parts, manufacturing and testing.

Battery Modules. Standard 24 VDC battery modules are available to provide electrical power to experiments operated in either of the two drop facilities. The modules use “starved electrolyte” lead-acid cells, (2VDC/5amp-hour). Most experiment packages require two or more battery modules. The unit battery module cost is approximately $450 including materials, parts, machining and wiring.